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THE NEXT GENERATION RECONNAISSANCE & EXPERIMENTAL UNMANNED VEHICLE (NGR&XUV) WAS AN EXPERIMENTAL EXERCISE CONDUCTED AT THE MOUNTED WARFARE TEST BED (MWTB) AT FORT KNOX, KY FROM JULY 7 TO OCTOBER 16, 1998. THE EXPERIMENT WAS PERFORMED AS DELIVERY ORDER (DO) #0073 UNDER THE LOCKHEED MARTIN ADVANCED DISTRIBUTED SIMULATION TECHNOLOGY II (ADST II) CONTRACT ADMINISTERED BY THE U.S. ARMY SIMULATION, TRAINING, AND INSTRUMENTATION COMMAND (STRICOM). THE EXPERIENT WAS SPONSORED BY TWO GEVERNMENT AGENCIES: THE GOVERNMENT'S CONCERTED TECHNOLOGY THRUST (CTT) FOR THE OFFICE OF THE SECRETARY OF DEFENSE'S ROBOTICS DEMONSTRATIONS, AND THE MOUNTED MANEUVER BATTLE LAB (MMBL), FORT KNOX, KY.

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NEXT GENERATION RECONNAISSANCE & EXPERIMENTAL UNMANNED VEHICLE (NGR&XUV)

DO #0073

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EXECUTIVE SUMMARY

The Next Generation Reconnaissance & Experimental Unmanned Vehicle (NGR&XUV) was an experimental exercise conducted at the Mounted Warfare Test Bed (MWTB) at Fort Knox, KY from July 7 to October 16, 1998. The experiment was performed as Delivery Order (DO) #0073 under the Lockheed Martin Advanced Distributed Simulation Technology II (ADST II) Contract administered by the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM). The experiment was sponsored by two Government agencies: the Government's Concerted Technology Thrust (CTT) for the Office of the Secretary of Defense's Robotics Demonstration, and the Mounted Maneuver Battle Lab (MMBL), Fort Knox, KY.

The NGR&XUV Program is an Advanced Concepts and Requirements (ACR) technology base project which plans to examine the characteristics and requirements for a robotics technology and its effectiveness in support of mounted maneuver warfare. NGR&XUV Demonstrations I and II were successful in demonstrating autonomous control and robotics operations. Demonstration II demonstrated its capabilities as a surrogate scout in a live experiment. Demonstration III (the current program) has planned for execution during FY97-02 Programmed Out-year Money (POM) cycle.

The NGR&XUV efforts conducted at the MWTB are multi-year-phased efforts conducted in support of Demonstration III. These efforts started in July of 1997 with Constructive Simulation (CS) I. This effort, Constructive Simulation II and Virtual Simulation (VS) I, used Modular Semi-Automated Forces (ModSAF) as well as man in the loop simulation. CS II and VSI involved the development of new ModSAF behaviors, required executing a ModSAF generated XUV, and focused on soldier in the loop issues in conjunction with the emerging results of the constructive simulations.

The purpose of the Experimental Unmanned Vehicle (XUV) experiment (the main experiment in the overall NGR&XUV effort) was to evaluate the effects on command and control and operational performance with addition of the XUV to the Battalion Task Force (TF) scout platoon and the Brigade Reconnaissance Troop. The experiment used Modular Semi-Automated Forces (ModSAF) to compare baseline organizations of the TF scout platoon and the Brigade Reconnaissance Troop implemented with various sensor packages. Data measures captured the target detection/reporting functions of the scout elements and operational performance of the TF and Brigade Combat Team.

The experiment will provide the Army with: insights on the relative impact on operational performance of the TF scout platoon and the Brigade Reconnaissance Troop when equipped with XUV in scout operations; insights into the design of the optimum soldier-machine interface; development of Tactics, Techniques, and Procedures (TTPs); and insights into the requirements for development of training support packages. This experiment will also provide objective and subjective findings, which will form the basis for future integration and development decisions, model improvements, and further experimentation.

The objectives of this experiment were as follows:

- To investigate the effects of XUV technology on command and control of the TF scout platoon and the Brigade Reconnaissance Troop.
- To investigate the effects on operational performance of the TF scout platoon and the Brigade Reconnaissance Troop with addition of various sensor packages on XUVs employed in scout operations.
- To investigate the impacts of XUV technology on the Battlefield Operating Systems (BOS).
- To investigate, and provide insights into the development of tactics, techniques and procedures (TTPs) for integration of the XUV into TF scout platoon and Brigade Reconnaissance Troop Operations.
- To investigate the requirements for the development of Training Support Packages (TSPs) for the XUV.
- To investigate the SMI requirements of the XUV.
- To provide insights into the optimum level of signature management for the XUV.

Also included into the NGR/XUV experiment were two other experiments that used the same scenarios and same trial runs to generate the data needed for their specific objectives. Instead of performing three separate experiments at eight to ten weeks each, all three experiments were combined in 4 sets of three weeks each. The second experiment was the Future Scout Calvary System (FSCS) experiment and the third experiment was the Semi-Autonomous Reconnaissance Operations (SARO) experiment. The purpose of the FSCS portion of this experiment was to refine operational requirements for the Future Scout and Cavalry System and to support the development of the Future Operational Capabilities. The experiment results will be used to validate or select sensor performance and user timeline input data for constructive modeling such as CASTFOREM and JANUS. Further, it is expected that such modeling will be used to conduct cost/benefit trade studies to substantiate perceived benefits to warfighting efficiency. The purpose of the SARO portion of this experiment was to evaluate the effects on control and operational performance with addition of a variety of semi-autonomous technologies to the reconnaissance operations of the Battalion Task Force (TF) scout platoon and the Brigade Reconnaissance Troop.

In accordance with the Government Statement of Work, the experiment's test trial window was separated into Phases A through D. Phase A was from July 7-24, Phase B was from August 14 – September 4, Phase C was from September 8-25, and Phase D was from October 5-23. All phases were completed ahead of schedule and the remaining time was allocated for excursion runs.

Also in accordance with the Government SOW, this Final Report includes a description of the experiment, its conditions and conduct, and lessons learned. This report addresses the interconnectivity of simulation systems, modifications to ModSAF and the manned

simulators, and the integration of Government Furnished software models. This report does not include discussion of data analysis nor conclusions as to whether the customer(s) achieved the objectives of the experiment.

1. INTRODUCTION

1.1 Purpose

The purpose of this Final Report is to document the ADST II effort which supported the NGR&XUV experiment. This report includes a full description of the experiment, its conditions, and lessons learned. A detailed description of the ModSAF modifications are found in the separately prepared document entitled the "NGR&XUV ModSAF Version Description Document (VDD) (CDRL A00C).

1.2 Contract Overview

The Next Generation Reconnaissance & Experimental Unmanned Vehicle (NGR&XUV) was an experimental exercise conducted at the Mounted Warfare Test Bed (MWTB) at Fort Knox, KY from July 7 to October 23, 1998. The experiment was performed as Delivery Order (DO) #0073 under the Lockheed Martin Advanced Distributed Simulation Technology II (ADST II) Contract administered by the U.S. Army Simulation, Training, and Instrumentation Command (STRICOM). The experiment was sponsored by two Government agencies: the Government's Concerted Technology Thrust (CTT) for the Office of the Secretary of Defense's Robotics Demonstration, and the Mounted Maneuver Battle Lab (MMBL), Fort Knox, KY.

1.3 Experiment Overview.

The NGR&XUV efforts conducted at the MWTB are multi-year-phased efforts conducted in support of Demonstration III. These efforts started in July of 1997 with Constructive Simulation (CS) I. This effort, Constructive Simulation II and Virtual Simulation (VS) I, used Modular Semi-Automated Forces (ModSAF) as well as man in the loop simulation. CS II and VSI involved the development of new ModSAF behaviors, required executing a ModSAF generated XUV, and focused on soldier in the loop issues in conjunction with the emerging results of the constructive simulations.

The purpose of the Experimental Unmanned Vehicle (XUV) experiment was to evaluate the effects on command and control and operational performance with addition of the XUV to the Battalion Task Force (TF) scout platoon and the Brigade Reconnaissance Troop. The experiment used Modular Semi-Automated Forces (ModSAF) to compare baseline organizations of the TF scout platoon and the Brigade Reconnaissance Troop implemented with various sensor packages. Data measures captured the target detection/reporting functions of the scout elements and operational performance of the TF and Brigade Combat Team.

The experiment will provide the Army with: insights on the relative impact on operational performance of the TF scout platoon and the Brigade Reconnaissance Troop when equipped with XUV in scout operations; insights into the design of the optimum soldier-machine interface; development of Tactics, Techniques, and Procedures (TTPs);

and insights into the requirements for development of training support packages. This experiment will provide objective and subjective findings, which will form the basis for future integration and development decisions, model improvements, and further experimentation.

1.4 Technical Overview

The technical approach to the NGR&XUV Experiment initially involved an analysis of the results of the findings in CS I, and the analysis of the results of a Feasibility Study funded during CS I. This was followed by the development of ModSAF behaviors and the integration of Government Furnish Items (GFI) into the experiment. The GFI products were from Army Research Lab (ARL) and consisted of a replication of the Operator Control Unit (OCU) and a micro terrain database.

The initial plan called for the initial development of ModSAF software to be developed and the Operational Support Facility (OSF) in Orlando, and the ARL products to be developed at the respective ARL sites. After the initial development of software products was complete, the software would be shipped to the OSF for further integration and then on to the MWTB for final integration. During the integration effort at the MWTB it was determined that the OCU product delivered by ARL could not contribute to the experiment in the time required and a ModSAF interface was substituted for the ARL product. The ARL micro-terrain database was used for Phase B, C, and D but to a lesser degree than initially desired due to hardware limitations. Upon completion of integration effort at the MWTB functional tests were conducted. Once the synthetic environment functional tests were completed, approval was given to proceed with the experiment. Each phase of the experiment started with two days of training by the MWTB staff, followed by the remaining days being allocated to experiment trials. A detailed discussion of Phase A, B, C, D are discussed in detail later in this document.

2. Applicable Documents

2.1 Government

- ADST II Work Statement for Next Generation Unmanned Vehicle (NGUV), August 97, 1997, AMSTI-97-WO37, Version 1.2

- ADST II Work Statement for Next Generation Reconnaissance & Experimental Unmanned Vehicle (NGR&XUV), February 11, 1998, AMSTI-98-WO13, Version 1

- Battle Lab Experiment Plan (BLEP) for Experimental Unmanned Vehicle (XUV), Future Scout and Cavalry System (FSCS), and Semi-Autonomous Reconnaissance Operations (SARO) for Constructive II/Virtual I Simulation, Mounted Warfare Testbed and Mounted Maneuver Battlespace Lab, ATZK-MW, Fort Knox, Kentucky, June 30, 1998

2.2 Non-Government

- ADST II Contract Data Requirements List (CDRL A00C), Next Generation Reconnaissance & Experimental Unmanned Vehicle ModSAF VDD, NGR/XUV-9800369, October 26, 1998.

3. System Description

3.1 System Configuration and Layout

The MWTB contains a variety of simulators, networks, ModSAF capabilities, displays for monitoring the battlefield, utilities to facilitate exercises, and automated data collection and reduction capabilities. The NGR&XUV Floor Plan is depicted in Figure 3.1-1.

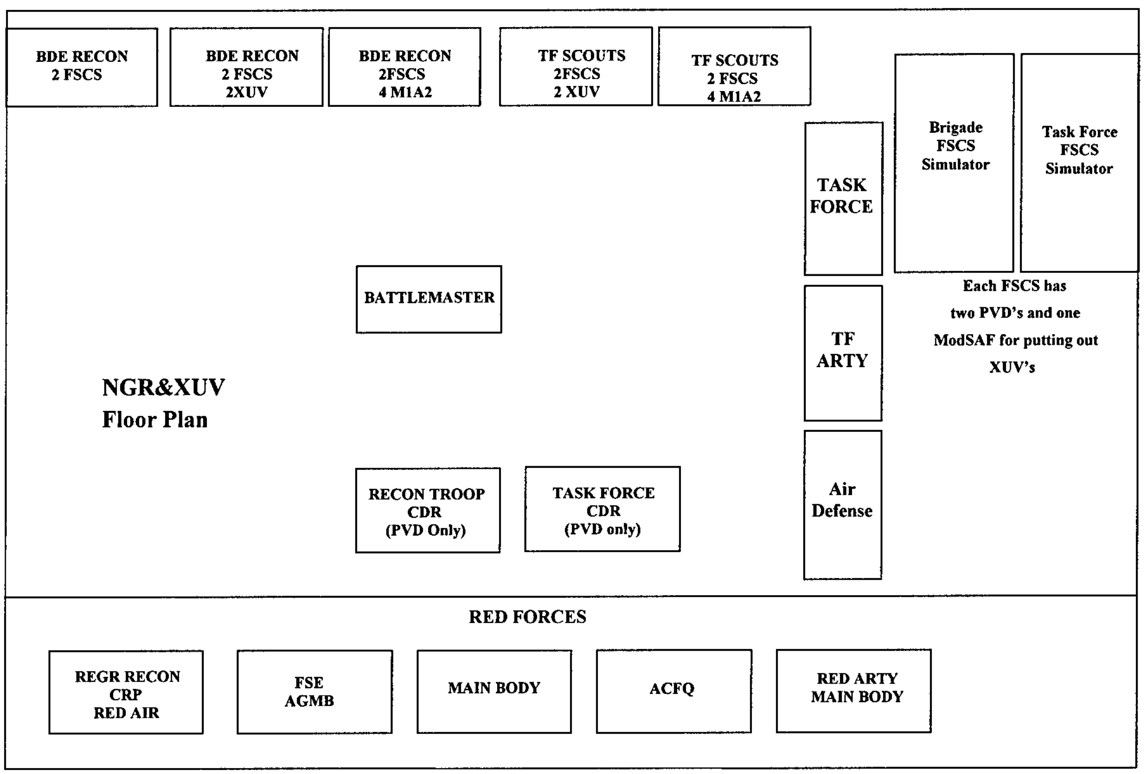

Figure 3.1-1 NGR&XUV Floor Plan

The experiment was conducted using assets interconnected on Ethernet local area networks (LANs) via twisted pair cable. Simulation assets used Distributed Interactive Simulation (DIS) 2.03 protocol. Table 3.1-2 lists assets used at the MWTB/ TRADOC Brigade and Below Virtual Battlefield (TB2VB).

ADST II ASSET	PURPOSE	PROTOCOL
ARSI Simulators (One from Raytheon and one from Lockheed Martin Vought)	Future Scout Simulators for Scout Platoon Leader and Platoon Sergeant	DIS 2.03
Stealth	Battlefield Visualization Display for Commander Role-player	DIS 2.03
ModSAF Workstations	Semi-Automated Forces for BLUFOR and OPFOR	DIS 2.03
Plan View Display	Terrain Map of the battlefield for Exercise Control (simulated C2 display)	DIS 2.03
Data Loggers	Record of DIS PDUs for Data Collection & Analysis	DIS 2.03
DIS Time Stamper	Time Stamp of DIS PDUs for Data Collection & Analysis	DIS 2.03
ASTi DIS Radios	Simulated voice radios for tactical and logistic communications	DIS 2.03

Table 3.1-2 ADST II MWTB/TB2VB Assets

In addition to the manned simulators and assets listed in Table 1 above, there were twenty SGI workstations, four Sun workstations, six Linux PCs and three Windows NT PCs.

3.2 Description of System Components

This section discusses the description, functionality and operation of the system components, which includes the Government Furnished Equipment (GFE) models and their integration with the hardware at the MWTB.

3.2.1 Experimental Unmanned Vehicle (XUV) Description.

The XUV is an unmanned vehicle designed to operate autonomously once mission instructions have been given. During this experiment, XUVs operated from 1 to 5 kilometers in advance of the manned scout vehicle (FSCS) to which they were assigned. Ranges of operation were on the order of 80 kilometers and 8 hours. Signature management technologies were implemented for XUVs in this experiment. XUVs were implemented as ModSAF entities. Modification made in ModSAF to create and control the XUVs will be discussed later in this document.

The XUV chassis is the Mobile Detection, Assessment, and Response System (MDARS) developed by Robotics Systems Technology for the U.S. Army Physical Security Equipment Management Office. MDARS is a small lightweight ATV type vehicle with diesel power and four-wheel hydraulic drive. It is 102 inches long, 42 inches high with a

12-inch ground clearance, and 65 inches wide. The XUV mast has two positions: extended and stowed. When stowed, the sensors are 55 inches above the ground. When extended, the sensors are 79 inches above the ground. The sensors implemented for this experiment were a subset of those described below for the FSCS, but were used in different packages. Threat vehicles detected by XUV appeared on the ModSAF display of the workstation which generates the XUVs, and on the Battalion Commander's workstation. Appearance of the threat icon constitutes the detection report.

3.2.2 Future Scout Calvary System (FSCS)

A Lockheed Martin Vought Reconfigurable Simulator and a Raytheon/Texas Instruments (TI) Reconfigurable Simulator were used to replicate the FSCS. The Future Scout and Cavalry System (FSCS) is a developmental, manned scout platform designed to increase not only the scout's mission success, but also his survivability. The FSCS will do this with an enhanced sensor capability coupled with signature management technologies that will provide our scouts with a capability overmatch and a greatly reduced probability of detection by threat sensor systems. The FSCS will also provide enhanced mobility, protection, and lethality capabilities over current scout platforms High Mobility Multi Purpose Wheeled Vehicle (HMMWV) and M3 Bradley Fighting Vehicle (BFV).

The FSCS is equipped with Forward-Looking Infrared (FLIR II+), an acoustic sensor, and Day TV. The FLIR II+ sensor identified here is representative in operational performance and is not meant to indicate actual FSCS candidate sensors. The FLIR II+ and Day TV will be mounted on a mast 5 meters high. A FLIR II+ and daylight optics (similar to the M1A2s) will be mounted on the hull as weapon sights. The acoustic sensor will also be mounted on the hull. The actual size of the FSCS will be 70 inches high, 130 inches wide, and 270 inches long and its main armament will be a 35mm gun. It is assumed that the vehicle protection will be 25% greater than that of the M3A3 Bradley Fighting Vehicle. Acoustic, Thermal, and Visual signatures will be reduced by 25% over the M3A3 Bradley Fighting Vehicle.

The FSCS sensor package will be mounted on a 5-meter extendable mast. The mast has three positions: stowed, locked into a hull-height (70 inches high) position for travelling, or extended to 5 meters for variant 1 and 10 meters for variant 2. The mast will be stowed when the vehicle comes under enemy fire. The Defensive Suite provides warning against laser and missile threats and provides defensive countermeasures of smoke and chaff. These countermeasures will be fired automatically in response to a missile threat.

3.2.3 Operator Control Unit

The OCU is the control unit of the XUV that has the ability to control up to four autonomous XUVs at one time. The OCU provides an interface for mission planning, mission rehearsal, situation display, scene visualization, mission monitoring, and data collection. The OCU will be mounted in different scout vehicles and controlled by a member of the scout vehicle. The OCU contains both a two-dimensional and a three-dimension view allowing the soldier to view the landscape in detail. The OCU uses standard Digital Terrain Elevation Data (DTED) from the National Imagery and Mapping Agency (NIMA). A terrain feature server is being utilized which provides an interface to

representations of vector product formatted thematic data (i.e. roads, lakes, brush, buildings, etc.). The two-dimension view is better know as the Combat Information Processor (CIP) and is used for the majority of the mission planning and creation of routes and movements. The three-dimensional view is known as the Virtual Geographical Information System (VGIS) and is used to display the terrain in a three-dimensional environment. This environment stores different terrain models within the database allowing the user to navigate through the terrain at real time and also allows the user to approach the area of interest giving a higher resolution depiction of the terrain.

Although the OCU was not used during the VS I experiment, there are plans to use the OCU during the next iterations of experiments currently scheduled for January 1999. During phase Delta of the VS I experiment, engineers from ADST II and ARL conducted a separate integration and test at the ARL facilities in Adelphi, MD. The purpose of the activity was to ensure the OCU and ModSAF integration was completed to ensure required capability was ready for the next set of experiments. After eight days of additional development and integration, the OCU and ModSAF was successfully integrated together and tested. Additional integration into the MWTB at Ft. Knox will be required but all pieces should be ready for the next experiment.

3.3 ModSAF Operations

Originally, ModSAF 4.0 was used in Orlando for initial XUV development. After initial integration at the MWTB, all changes to ModSAF 4.0 were moved and integrated into the MWTB ModSAF 3.0 tree. One exception was that the OCU communications libraries were not moved to 3.0 since the OCU was not used for the VS I experiment. A variant of ModSAF 3.0 was used in the FSCS simulators for control of the XUV to replace/simulate the OCU interface

All ModSAF workstations were connected to Network Port 3033 (UDP) which was different then the UDP port used for the FSCS simulators and the DIS radios. The DIS radios used a completely separate port to relieve network traffic for the ModSAF workstations, and the FSCS simulators used the default DIS port (UDP port 3000). The main purpose for the simulators using the default port was that the simulators could not handle the volume of traffic. Therefore a filter was placed between the ModSAF network and the simulators which filtered out all entities not within 20 kilometers of the simulators.

3.3.1 ModSAF Enhancements

ModSAF lacked the detailed behaviors required for scout vehicles. Therefore, to model the XUV vehicle behaviors for CS II/VS I, additional ModSAF behaviors were required. For CS II/VS I, five ModSAF behaviors were created using the CATT Task Database Combat Instruction Sets (CIS) and incorporated into XUV ModSAF.

In addition, the route utility library and two communications libraries were required. The route utility library is primarily responsible for generating a concealment map around the XUV vehicle position. The first communications library provides suite of Protocol Data Unit (PDU) reports. The second communication library receives OCU request and

generates the appropriate behavior. An explanation of these behaviors and libraries are outlined in the sections below:

3.3.1.1 Tactical Road March (libutactrdmarch)

The Tactical Road March behavior, libutactrdmarch is modeled from the ModSAF behavior "Unit Traveling" (libutraveling). The Tactical Road March behavior collects data concerning the road route as the XUV travels. Specifically, the behavior calls three functions for verifying road conditions. The function utrmar_is_on_road verifies that the soil of the route being traveled is a road. The function utrmar_check_grade verifies that the slope of the route is less than the maximum climb angle of the vehicle. The function utrmar_road_curve_check records the position and radius of curvature of any portion of the road route that is greater than the vehicles maximum turning angle. Upon the successful navigation of the user selected route, the behavior will call the libxuvcommunication function xuvcom_send_sit_report and report its findings by way of an XUV report experimental DIS PDU.

3.3.1.2 Tactical Move (libutacticalmove)

The Tactical Move Behavior, libutacticalmove is also modeled from the ModSAF behavior "Unit Traveling" (libutraveling). The Tactical Move Behavior travels a user specified cross-country route. The behavior utilizes the vehicle spotter behavior to search for enemy vehicles. If enemy vehicles are detected, the behavior will first call the libxuvcommunication function xuvcom_send_contact_report and report the detection for each new enemy vehicle via a Contact Report PDU. Then the libxuvcommunication function xuvcom_send_spot_report is called once for all the vehicles and an XUV Spot Report PDU is generated. The route utility (librouteutil) function rtutil_draw_concealment_map will be called and a concealment map will be drawn with respect to the XUV vehicle. The concealment map appears as a partially shaded gray block around the XUV vehicle. The non-shaded areas within the block represent the portion of the concealment map which is detectable by the enemy vehicle. An XUV located in the darker shade of gray within the block is not detectable by the enemy vehicle.

3.3.1.3 Observation Post (libvobspost)

The Observation Post Behavior, libvobspost is a vehicle level behavior. In this behavior, the XUV will travel a user-designated route to a user-designated location, where an Observation Post (OP) will be established. The user has the option to specify whether the XUV should follow contours along the route. The OP is usually established behind a hill so that the XUV can raise its mast above the hill to observe the sector under surveillance, while remaining hidden. The user also designates the sector under surveillance by assigning right and left sector boundaries on the GUI terrain. When the XUV reaches the OP location, the behavior will designate it as either an OP or move the XUV to the nearest Hidden Post (HP). The HP is chosen if an enemy vehicle located within the surveillance sector is able to spot the XUV at the original OP location. The HP is the nearest point to the original OP location where the XUV is not detectable by an enemy vehicle. If the user chose the Draw Concealment Map option upon setting up the

behavior, the route utility (librouteutil) function rtutil_draw_concealment_map will be called. This function will generate a concealment map with respect to the XUV vehicle. If an enemy vehicle is detected during this behavior, the libxuvcommunication function xuvcom_send_spot_report is called and an XUV report PDU is generated.

3.3.1.4 Route Reconnaissance (libvrouterecon)

The Route Reconnaissance behavior is a unit level behavior assigned to two XUVs. In this behavior, the XUV units proceed to a user designated start point of the route. The user has the option to specify whether the XUVs should follow contours along the route. Upon reaching the start point, the XUVs spawn an Over Watch behavior if the units are in the user designated stealth mode. A Tactical Move behavior is spawned if the units are in the user designated aggressive mode. As the reconnaissance begins, a concealment map is drawn and Contact and Spot Report PDUs are generated if enemy vehicles are detected. As the XUVs approach a user-designated area of interest, either the Tactical Move or Over Watch behaviors are suspended. The closest XUV will spawn a Move behavior and proceed to the center of the area. The remaining XUV spawns an Observation Post behavior and proceeds to survey the other XUV in the area of interest. Upon completion, the vehicles proceed on the route, resuming either the Over Watch or Tactical Move behaviors to the next area of interest, where once again the Move and Observation Post behaviors are spawned. This behavior ends when the XUVs reach the user designated end point of the route. A Route Reconnaissance PDU report is generated.

3.3.1.5 Obstacle Reconnaissance (libureconobst)

The Obstacle Reconnaissance behavior is a unit level behavior assigned to two XUVs. In this behavior, the XUVs are tasked to investigate a user-designated obstacle. As the behavior begins, one XUV spawns an Observation Post behavior. The other XUV moves toward the obstacle. Upon reaching the obstacle, the XUV attempts to bypass it. If successful, the XUV will spawn an Observation Post behavior on the other side of the obstacle. If the XUV can not bypass the obstacle, it will remain at its present location. The XUV will generate the appropriate Obstacle and Bypass PDU reports.

3.3.1.6 Route Utility (librouteutil)

The Route Utility library, librouteutil is primarily responsible for generating a concealment map around the XUV vehicle position. The primary global functions contained in this library are summarized below:

Function	Purpose
rtutil_follow_contours	Finds the highest point on each segment of a route and alters the route to bypass around the point.
Rtutil_create_concealment_map	Creates the concealment map about the XUV.
Rtutil_generate_concealment_map	Function which kicks off the concealment map process.
rtutil_in_concealed_area	Verifies whether the XUV is located in a concealed area. Returns TRUE or FALSE.
Rtutil_approaching_exposed_area	Checks XUV route to see if vehicle is about to leave a concealed area. Sets variable need_to_stop to TRUE if condition warrants.

rtutil_get_friends_foes	Collects and updates a list of all friendly and enemy vehicles identified by libvspotter. New foes result in the generation and/or update of the concealment map.
Rtutil_draw_concealment_map	Function which draws the concealment map on the gui around the XUV.
rtutil_find_observation_point	Function examines an area of interest on the ctdb. Identifies and records number and location of both observation points and hidden points for the XUV with respect to enemy vehicles. Returns the observation point count if greater than zero.

Table 3.3.1.6-1 Route Utility library functions

3.3.1.7 XUV Communications (libxuvcommunications)

The XUV Communications library consists of a suite of nine (9) different PDU reports. The name of each XUV PDU report structure, with an accompanying description of their respective contents is provided in the table below.

XUV PDU Report	Description
xuv_contact_report	Enemy contact report that specifies enemy type and general direction of contact.
xuv_spot_report	Report generated upon detection of enemy. Report specifies enemy size, activity, location and real world time.
xuv_sit_report	Situation report that specifies real world time, the number of enemy vehicles and the number and type of both defensive obstacles and supplies. Also reports the enemy activities, the number and coordinates of friendly locations and the XUV operational status. A text message is also provided.
xuv_bridge_report	This report identifies the type and location of crossing structures. The structure length, width and height are reported. The difficulty in crossing the bypass is reported if this information is available.
xuv_cross_report	This report is generated after the XUV has crossed a water obstacle. The method of crossing, crossing location, length, maximum depth and both entry and exit slopes are provided.
Xuv_route_recon_report	This report is generated upon reconnaissance of a route. The start and end coordinates are reported. The type of route (road, trail, etc.) and the route class (wheeled, tracked) are identified. A weather code is assigned to the route. This code provides an assessment as to under what weather conditions the route may be traveled. Travel velocity assessments are also provided. The number and location of critical points encountered along the route are provided.
xuv_obstacle_report	This report provides the time, location and type of obstacle encountered by the XUV. The number and description of enemy weapon types influencing the obstacle (if applicable) are provided.

xuv_bypass_report	This report is used to describe bypasses by providing the start and end coordinates, the bypass length, surface type and maximum grade.
xuv_shell_report	This report is used to indicate attack by indirect fire on a friendly unit. The XUV location and the direction of the attack from the XUV perspective are provided. Also reported are the detonation location and time of detonation.

Table 3.3.1.7-1 XUV reports and descriptions

3.3.1.8 OCU Communications (libuocurequest)

The OCU Communication library is the library that receives vehicle plans and platoon plans from the OCU and then translates the plans into ModSAF behaviors for the constructive XUVs. Since one OCU plan could contain any number of behaviors, ModSAF translates the plan and executes one behavior at a time. Once a behavior is near completion, (~ 20 meters to the next waypoint/ behavior), ModSAF then executes the next behavior. The following is a list of the current behaviors that the XUV ModSAF can receive from the OCU:

- Tactical Move
- Tactical Road March
- Observation Post
- Route Reconnaissance

3.3.2 Data Logger

The Data Logger is an ADST II asset that captures the network traffic and places the data packets on a disk or tape file. The Data Logger performs the following functions:

a. Packet Recording - Receives packets from the DIS network time stamps and then writes to a disk or tape.

b. Packet Playback - Packets from a recorded exercise can be transmitted in real time or faster than real time. The Data Logger can also suspend playback (freeze time) and skip backward or forward to a designated point in time. The logger can be controlled directly from the keyboard or remotely from the Plan View Display (PVD). Playback is visible to any device on the network (PVD, Stealth Vehicle, a vehicle simulator, etc.).

c. Copying or Converting - Files are copied to another file, which can be on the same or a different medium; and files from the older version of the Data Logger can be converted to a format compatible with the current version of the Data Logger.

For the experiments, three data loggers were employed to capture the exercise. For the logging on the main simulation network, a Sun Sparc 10 with 128 MB RAM, total hard disk storage of 9GB, and the Solaris 2.5 operating system was used. For DIS Logging backup, a Sun Ultra 1 with Solaris 2.5, 128 MB RAM, and total hard disk storage of 9GB

was used. For the DIS Radio network a Sun Sparc 10 with 128 MB RAM, total hard disk storage of 9Gb, and the Solaris 2.5 operating system was used.

3.3.3 Time Stamper

The MWTB provided a Time Stamper that consisted of: a time code generator (clock); an IBM-compatible Personal Computer (PC) loaded with the MS-DOS operating system; and a coaxial cable connecting the two units. This time code generator produced time data in days, and since 1 January, in hour/min/sec/1/1000 second in IRIG B format. The PC runs a program that reads the IRIG B time signals and converts them into time data to be sent out as a DIS 2.03 Time Stamp PDUs once a minute. The DIS Logger receives the time stamp in PDUs and adjusts its internal clock accordingly. The DIS PDUs on the simulation network are then tagged with this time as they are sequentially received by the DIS Logger.

A second Time Stamper PC attached to same clock was used to time stamp the DIS logger that captured the Transmitter and Signal PDUs. This allows perfect correlation of the data sets logged on both loggers.

3.3.4 MetaVR Stealth

Three MetaVR Stealths were used for the NGR/XUV Experiment. One stealth was used for the test director to view the battle from a three dimensional view. Each of the other two stealths was placed in the FSCS simulator to simulate the real world picture that the XUVs would return to the scouts. The stealth was attached to one of the two XUVs that it controlled and would only turn 360 degrees around the robots. The stealth was locked so not to allow the soldiers to use them to fly around the database. The soldiers could only use the stealths to see what the XUVs were actually visualizing.

3.3.5 DIS LAN Network Configuration

A DIS LAN configuration was used with 10 BaseT standard cable. All workstations, simulators and image generators on the main simulation network were connected to a Cabletron MMAC plus, providing true 10Mb/s bandwidth to each port.

3.4 Database and Scenario Development

The intentions for the XUV experiments were to execute the simulations on a micro terrain database with grid post spacing every 1 to 10 meters. ARL had the role of taking the existing 125-metter post Compact Terrain Database (ctdb) database and create the micro terrain. Just prior to the Alpha runs, ARL produced a 10-meter post ctdb database for Ft. Hood. After testing the micro terrain, problems were found with the elevation data, and the size of the database was two large. The size of the database affected the speed and usability of the terrain, so the decision was made to use the original 125-meter post ctdb for the Alpha runs. Just prior to the Bravo runs, ARL produced a 50-meter post that passed the integration and testing at the MWTB. The size of the database was also acceptable and the decision was made to use the 50-meter post database only during the SARO run of Bravo, Charlie, and Delta. The 50-meter post database was only available

for Ft. Hood and was not provided for the STOW-E database. The STOW-E ctdb was of a TIN format and the ARL tools were unable to convert this database to a micro terrain.

The 50-meter ctdb Ft. Hood database was also sent to MetaVR, and their engineers were able to convert this database to their database format. This was essential to ensure the XUV three-dimensional view was equivalent to the ModSAF database. The Ft. Hood database that the two FSCS simulators used were not converted, and further investigation into that possibility needs to be pursued prior to the next excursion.

Scenarios used for the CS II/VS I experiment depicted a Task Force conducting Defense and Movement to Contact operations. The scenarios included Operations Orders (OPORDs), Fragmentary Orders (FRAGOs) and overlays to support the mission. The Mounted Maneuver Battle Lab and ADST II Lockheed Martin Services Group (LMSG) MWTB personnel developed the orders and overlays.

4. Conduct of The Experiment

The experiment was scheduled with four phases. Phase A was July 7-24, Phase B was August 14 to September 3, Phase C was September 8-25, and Phase D was October 5-19. Each Phase was designed to start with two days of troop training with the remaining days were dedicated to trial runs.

4.1 Troop Training

In order to get the maximum benefit from the experiment, two days were dedicated for troop training to bring the soldiers up to a level of confidence on the systems prior to starting the experiment. The MWTB staff provided classroom and hands-on training consisting of familiarization and orientation on the actual simulation systems and vehicle mockups.

4.2 Pilot Test

4.3 Experiment and Trial Runs

The trial runs for Phase A were completed four days ahead of schedule and the remaining four days were dedicated for excursion runs. During Phase A a total of thirty trial runs and eight excursion runs were completed. A detailed description of Phase A is found at Appendix A.

The trial runs for Phase B were completed one day ahead of schedule. The remaining days were dedicated for excursion runs. During Phase B a total of Thirty-six trial runs and eight excursions runs were completed. A detailed description of Phase B is found at Appendix B.

The trial runs for Phase C were completed two days ahead of schedule and the remaining two days were dedicated for excursion runs. During Phase C a total of thirty-four trial

runs and six excursions runs were completed. A detailed description of Phase C is found at Appendix C.

The trial runs for Phase D were completed four days ahead of schedule. There were no excursion runs completed for this phase. During Phase D a total of thirty-four trial runs and no excursion runs were completed. A detailed description of Phase D is found at Appendix D.

5. Observations and Lessons Learned

- **Observation #1**

Some GFE items were not used during the experiment.

- **Discussion #1**

After two attempts at integration, the OCU developed by ARL was not used in the experiment. The primary reasons for the OCU not being available are due to ARL personnel not understanding the total technical requirements of the OCU to operate in a DIS environment and personnel turbulence.

- **Lesson Learned #1**

More Technical Interchange Meetings (TIM) should have been scheduled and had the involvement of the ADST II engineering team.

- **Observation #2**

Some GFE items were used but to a lesser degree of fidelity that originally planned.

- **Discussion #2**

The micro-terrain database developed by ARL was used at the fidelity of a fifty-meter post. The initial requirement was a one-meter post. Due to the hardware requirements for disk space and storage, the one-meter requirement was raised to ten meters. This was still not adequate, and the final development ended up at fifty meters. The fifty-meter solution could have possibly been reduced. However, due to schedule considerations the fifty-meter solution was used in order to start and complete the experiment as planned. It is anticipated that a better resolution database will be available for the next series of experiments.

- **Lesson Learned #2**

More Technical Interchange Meetings (TIM) should have been scheduled and had the involvement of the ADST II engineering team.

- **Observation #3**

Administration and management time and costs of this program were more than other efforts of this size.

- **Discussion #3**

Changes in schedule and funding actions were not always coordinated with the ADST II engineering team. The last schedule change was a complete surprise to the STRICOM and ADST II engineering team. This impacted the engineering effort and milestones that had been established. The funding allocation came in small increments and did not correspond to milestones. The arrival of funding was also later than anticipated, caused confusion, and caused the realignment of engineering tasks.

- **Lesson Learned #3**

The Battle Lab should establish a better communications link and coordinate among it's staff to ensure all the individuals involved in schedule, technical requirements and funding allocation are in complete agreement at the kick-off meeting.

6. Conclusion

The NGR&XUV II experiment accomplished it's primary goal which was to evaluate a concept which would redefine future concepts and requirements with the use of robotics to enhance the decision making capability for the Commander and his staff in the future. The success of this initial effort has resulted in the approval and expansion for additional evaluations to further redefine these requirements. Currently two more experiments are scheduled in the next twelve months. These future experiments are currently the number one priority of the Fort Knox Battle Lab.

7. Points of Contact

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Acronym List

AAR	After Action Review
ACR	Advanced Concepts Research
ADST	Advanced Distributed Simulation Technology
ARL	Army Research Lab
ARPA	Advanced Research Projects Agency
ARSI	ARPA Reconfigurable Simulator Initiative
BFV	Bradley Fighting Vehicle
BLEP	Battle Lab Experiment Plan
BLUFOR	Blue Forces
BOS	Battlefield Operating Systems
C2	Command and Control
CCTT	Close combat Tactical Trainer
CDRL	Contract Data Requirements List
CIP	Combat Information Processor
CIS	Combat Instruction Sets
CS	Constructive Simulation
ctdb	Compact Terrain Database
CTT	Concentrated Technology Thrust
DO	Delivery Order
DIS	Distributed Interactive Simulation
DTED	Digital Terrain Elevation Data
FRAGO	Fragmentary Order
FSCS	Future Scout Cavalry System
GFE	Government Furnished Equipment
GFI	Government Furnished Items
HMMWV	High Mobility Multi- Purpose Wheeled Vehicle
HP	Hidden Post
H/W	Hardware

LAN	Local Area Network
LMC	Lockheed Martin Corporation
LMSG	Lockheed Martin Service Group
MDARS	
ModSAF	Modular Semi-Automated Forces
MMBL	Mounted Maneuver Battle Lab
MWTB	Mounted Warfare Test Bed
NGR&XUV	Next Generation Reconnaissance and Experimental Unmanned Vehicle
NIMA	National Imagery and Mapping Agency
OCU	Operator Control Unit
OP	Observation Post
OPFOR	Opposing Forces
OPORD	Operations Order
OS	Operating System
OSF	Operational Support Facility
PC	Personnel Computer
PDU	Protocol Data Unit
POC	Point of Contact
POM	Program Objectives Memorandum
PVD	Plan View Display
RIU	Radio Interface Unit
SA	Situational Awareness
SAF	Semi-Automated Forces
SARO	Semi-Autonomous Reconnaissance Operations
SGI	Silicon Graphics Industries
SOW	Statement of Work
STRICOM	(US Army) Simulation Training and Instrumentation Command
TB2VB	TRADOC Brigade and Below Virtual Battlefield

TIM	Technical Interchange Meeting
TF	Task Force
TOC	Tactical Operations Center
TRADOC	Training and Doctrine Command
TSP	Training support Package
TTP	Tactics, Techniques, and Procedures
UAV	Unmanned Aerial Vehicle
UDP	User Datagram Protocol
VDD	Version Description Document
VGIS	Virtual Geographical Information System
VS	Virtual Simulation
XUV	Experimental Unmanned Vehicle

Appendix A – Exercise Phase A

Phase A was July 7-24 and had 30 trial runs with 8 excursions runs. The following is a brief synopsis of this phase of the experiment.

- Two trial runs were conducted with RA's only
- Five trail runs were conducted with Troops; additional trial runs were required to test the new version of ModSAF 3.0 that include the XUV behaviors from ModSAF 4.0.
- A total of 40 trial runs were conducted
- Brigade FSCS and Task Force FSCS crashed only once.
- 35 crashed on SAF workstations
- 20 perfect runs
- 2 re-runs

Appendix B – Exercise Phase B

Phase B was August 14-September 3 and had 36 trial runs with 8 excursions runs. The following is a brief synopsis of this phase of the experiment.

- Four trail runs were conducted with Troops
- A total of 46 trial runs were conducted
- Brigade FSCS crashed once TF FSCS crashed three times.
- 29 crashed on SAF workstations
- 34 perfect runs
- 1 re-run

Appendix C – Exercise Phase C

Phase C was September 8-25 and had 34 trial runs with 6 excursions runs. The following is a brief synopsis of this phase of the experiment.

- Two trail runs were conducted with Troops
- A total of 42 trial runs were conducted
- Brigade FSCS crashed twice.
- 29 crashed on SAF workstations
- 25 perfect runs
- 1 re-run

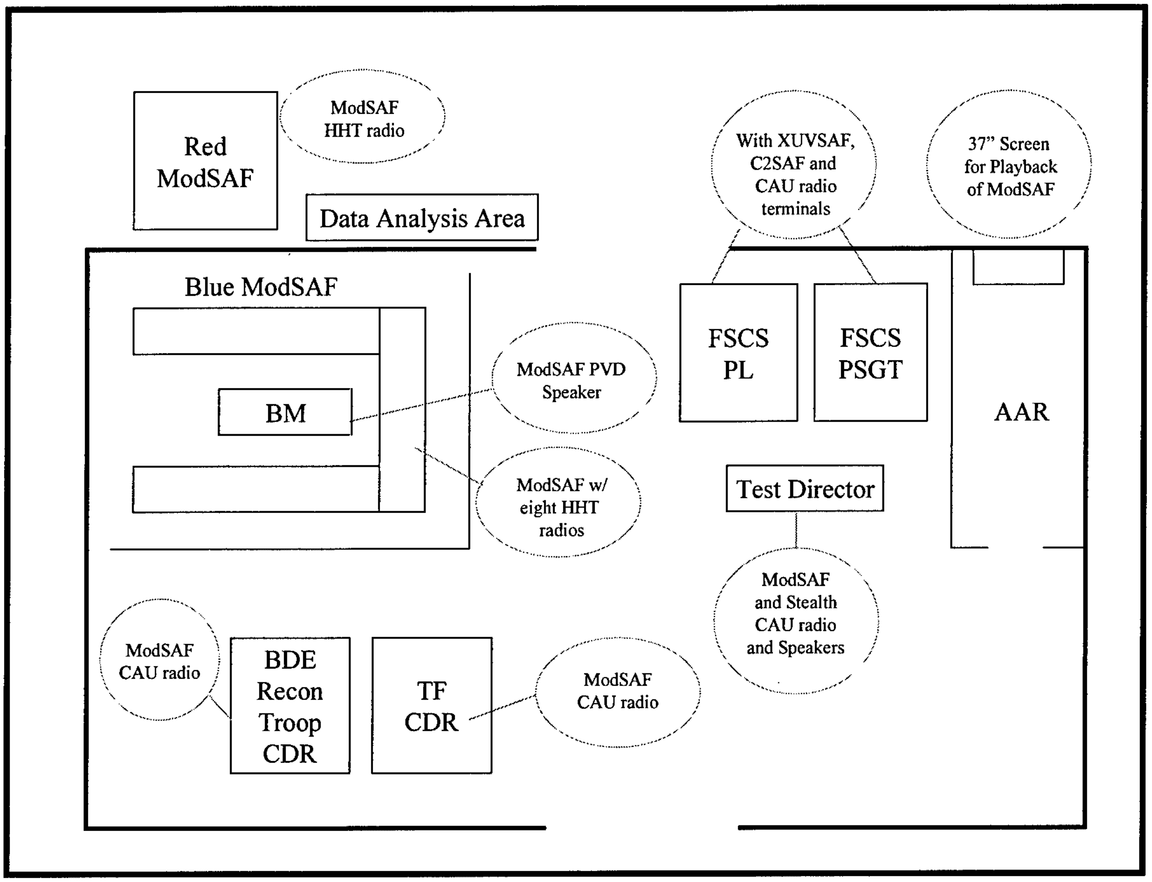
Appendix D – Exercise Phase D

Phase D was October 5-19 and had 34 trial runs. The following is a brief synopsis of this phase of the experiment.

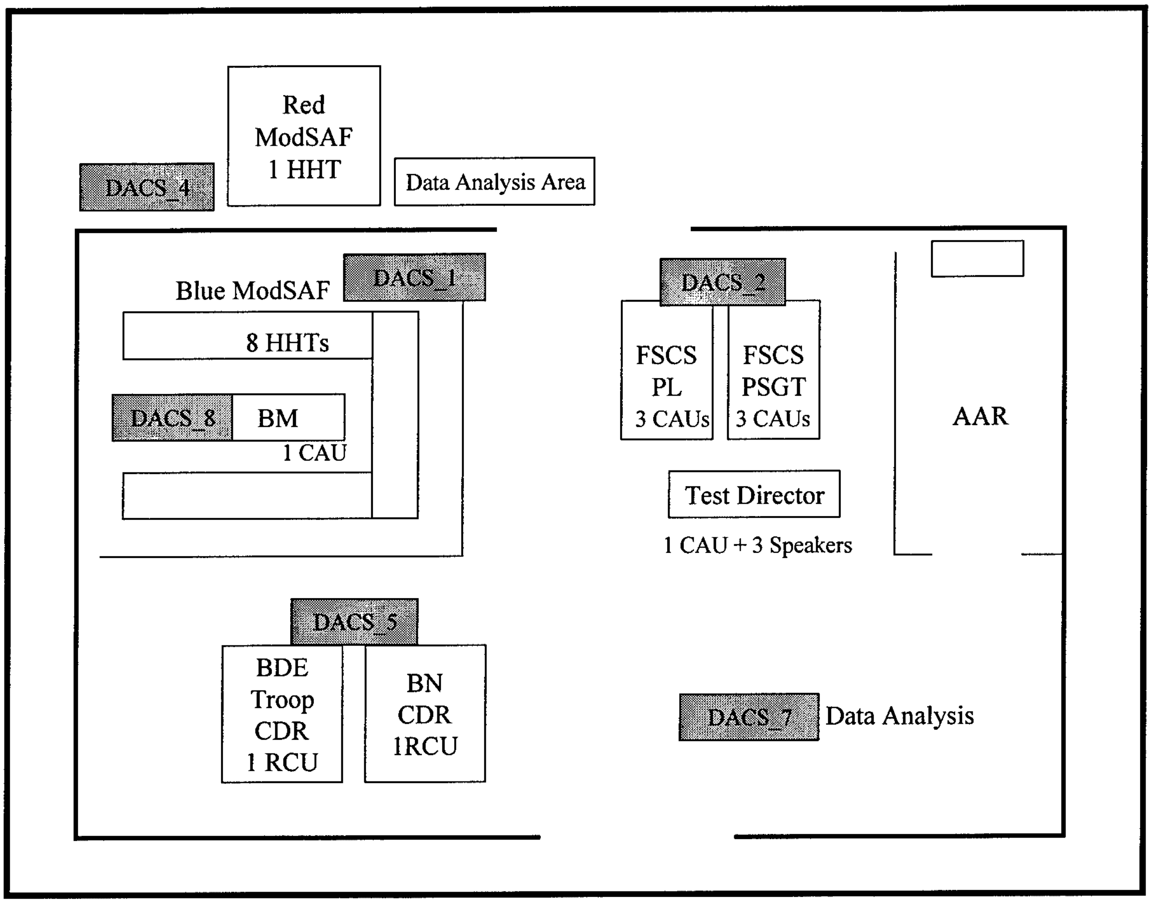
- Three trail runs were conducted with Troops
- A total of 35 trial runs were conducted
- Brigade FSCS crashed once and TF FSCS crashed twice.
- 19 crashed on SAF workstations
- 22 perfect runs
- 2 re-run

Appendix E – Additional Drawings

The following drawing shows the test infrastructure that includes the ASTi DIS radios, Battlemaster, Test Director and the Data Analysis areas.



The following drawing shows the experiment layout and highlights the ASTi DACS that were used for both the tactical and test director nets.



The following table describes the XUV ASTi radio configuration used for the XUV experiment:

DACS#	Ref_Des	Model#	Site_ID	Host_ID	Entity_ID	DIS_ID	Default_Pos	IP-Address	UDP_Port	Config File	Model File
		cfg	mdl	mdl	mdl	cfg	mdl	cfg	cfg		
1	Blue MS	1	3	10	1	3:10:01	0	166.30.31.150	6994		cmd_mt1.mdl
2	FSCS LMV	1	3	20	1	3:02:01	200	166.30.31.151	6994		fscs_lm.mdl
	FSCS Ray	2	3	20	2	3:02:01	400				fscs_ra.mdl
	(Test Director)										
4	Red MS	1	3	40	1	3:04:01	1000	166.30.31.153	6994		red_ms.mdl
5	Bde Tr Cmdr	1	3	50	1	3:50:01	1200	166.30.31.154	6994		arrow_m.mdl
	Bn Cmdr										
7	Data Analysis	1	3	70	1	3:07:01	0	166.30.31.156	6994		
8	Battle Mstr	1	3	80	1	3:80:01	0	166.30.31.157	6994		bttlmstr.mdl